OXYGEN SENSOR WITH HEATER

BACKGROUND OF THE INVENTION

The present invention relates generally to an oxygen sensor for detecting concentration of oxygen contained in exhaust gas emitted from an internal combustion engine. More particularly, the invention is concerned with such an oxygen sensor having a bar-shaped heater disposed in an elongate bore formed in a tubular solid electrolyte body.

In the art of controlling an air-fuel (A/F) ratio of an internal combustion engine for an automotive vehicle or for other applications, it is known to use an oxygen sensor which employs a mass of zirconia or other solid oxygen-ion conductive electrolyte to detect a content or concentration of oxygen in exhaust gas produced by the engine, according to the principle of an oxygen concentration cell. For example, such an oxygen sensor uses a solid electrolyte body of zirconia which is provided on its inner and outer surfaces with porous platinum electrodes, respectively. The electrode on the inner surface which defines an inner elongate bore in the zirconia body, is exposed to an ambient atmosphere and serves as a reference electrode (anode) which is exposed to a reference gas whose oxygen concentration is known. On the other hand, the electrode provided on the outer surface of the zirconia body is exposed to exhaust gas to be measured, so that this electrode serves as a measuring electrode (cathode) to monitor oxygen content of the exhaust gas. This oxygen sensor measures the oxygen concentration in the exhaust gas by measuring an electromotive force which is induced in response to a difference in the oxygen concentration between the reference and measuring electrodes.

However, the induced electromotive force is unstable until the solid electrolyte has been heated to a given point. Thus, the above type of oxygen sensor suffers a drawback that it is incapable of effecting an accurate control of an air-fuel ratio of the engine while the temperature of the exhaust gas of the engine is relatively low, for example while the engine is idling or immediately after the engine is started in its cold condition.

To solve such a drawback experienced in the art, it has been proposed to positively heat a solid electrolyte body by inserting a heater into an elongate cylindrical hole formed in the electrolyte body. For instance, Japanese Patent application laid open in 1979 under Publication No. 54-13396 discloses a heater which consists of an insulator bar and a heating wire (resistance wire) wound on the surface of the insulator bar. Further, Japanese Patent application laid open in the same year under Publication No. 54-22894 shows a so-called sheathed heater which uses a resistance coil wire disposed in a metal sleeve which is filled with a powdered electrically insulating material of high thermal conductivity so as to secure the coil wire in the metal sleeve.

Such proposed oxygen sensors equipped with a heater are disadvantageous in that their solid electrolyte is susceptible to excessive heat when the temperature of the exhaust gas of an internal combustion engine is elevated, whereby the porous platinum electrodes tend to be sintered with a result of reducing a rate of reaction of the measuring electrode to the exhaust gas, or a spinel coating layer protecting the electrodes tends to crack or flake off. Further, the heater is subject to an excessively high temperature due to a combined effect of its self-heating and exposure to heat of the exhaust gas, thereby suffering breakage of its inner resistance wire.

On the other hand, an effort to restrain heat generation of the heater to minimize such disadvantages as indicated above, will create another incovenience of insufficient heating of the solid electrolyte while the exhaust gas is low in temperature, or undesired requirement of extra time for heating the solid electrolyte after the start of the engine, before the electromotive force induced by the sensor reaches a level for accurate detection of the oxygen concetration.

The above inconvenience of insufficient heating of the solid electrolyte is serious, particularly when a battery voltage to actuate the heater is low, that is, immediately after the engine is started or while the engine is operated in a cold state. On the contrary, when the battery voltage rises with the engine speed, the temperature of the exhaust gas is elevated. This will aggravate the previously indicated drawback of excessive heating of the solid electrolyte.

Further, a heater used in the traditional oxygen sensor is simply inserted in the hole of a solid electrolyte. That is, no considerations are given to the position of a heating element or resistor such as a resistance wire or coil with respect to the solid electrolyte, for effective and suitable heating of the electrolyte. It is also noted in the art that a relatively large gap is generally provided between the solid electrolyte and the heater so that the ambient air used as reference air may be well circulated in a bore or hole in the solid electrolyte body. Since this gap functions as a thermal barrier to heat transfer from the heater to the solid electrolyte, the heating of the electrolyte tends to be insufficient while the temperature of the exhaust gas is low. Further, an attempt to use a heating element having larger capacity to eliminate this inconvenience will lead to the previously discussed problem of excessive heating of the solid electrolyte when the exhaust gas is heated to an appreciable extent.

SUMMARY OF THE INVENTION

It is accordingly an object of the present invention to provide an improved oxygen sensor having a heater inserted in an elongate bore formed in a body of solid electrolyte, which is durable and reliable in operation even in comparatively varying environmental conditions.

Another object of the invention is to provide such an oxygen sensor having an improved heater which requires less time for sufficient heating of the solid electrolyte even when the temperature of an exhaust gas to be monitored is relatively low, and which protects itself and the solid electrolyte against overheating even when the temperature of the exhaust gas is relatively high.

According to the present invention, there is provided an oxygen sensor comprising: a tubular solid electrolyte body having an elongate bore which is closed at one end of the tubular solid electrolyte body and open at the other end, and further having reference and measuring electrodes on inner and outer surfaces thereof, respectively; a housing which supports or retains the body of solid electrolyte such that the outer surface of the latter is exposed at the closed end to exhaust gas, and such that the elongate bore in the tubular solid electrolyte body of solid electrolyte is held in gas-tight condition with respect to the exhaust gas; and a bar-shaped heater inserted in the elongate bore in the tubular solid electrolyte body. The bar-shaped heater comprises a heating resistor having a positive temperature coefficient of